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(पहला पुनरीक्षण)

Indian Standard

LINE TRAPS FOR AC POWER SYSTEMS — METHODS OF TESTS

(First Revision)

UDC 621. 315. 052. 63 : 621. 316. 9 : 621. 372. 54 : 620. 1

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Power Line Carrier Systems and Associated Telecontrol Equipment Sectional Committee, LTD 25

FOREWORD

This Indian Standard (First Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Power Line Carrier Systems and Associated Telecontrol Equipment Sectional Committee had been approved by the Electronics and Telecommunication Division Council.

This standard was originally published in 1978 and this revision has been undertaken to take into account latest international practices. In this revision, this standard is largely aligned with IEC Publication 353-1989 (Second Edition) 'Line traps for AC power systems'.

In reporting the results of a test or analysis made in accordance with this standard, if the final value, observed or calculated, is to be rounded off, it shall be done in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'.

Indian Standard

LINE TRAPS FOR AC POWER SYSTEMS — METHODS OF TESTS

(First Revision)

1 SCOPE

1.1 This standard covers methods of tests for line traps inserted into high voltage ac transmission lines to prevent undue loss of carrier signal power and to minimize interference from carrier signalling system on adjacent transmission lines.

2 REFERENCES

2.1 The following Indian Standards are necessary adjuncts to this standard:

IS No.	*Title*
2026 (Part 2) : 1977	Power transformers: Part 2 Temperature-rise
3070 (Part 1) : 1985	Lighting arresters for alternating current systems: Part 1 Non-linear resistor type lighting arresters (*second revision*)
6209 : 1982	Methods of partial discharge measurement (*first revision*)
8792 : 1995	Line traps for AC power systems — Specification (*first revision*)

3 SYMBOLS

I_N = continuous rated current

I_{KN} = steady state component of short-circuit currents

J = short-circuit current density

T = inverse of temperature coefficient

U = voltage developed across the line trap at rated power frequency by rated short-time current

U_m = maximum system voltage

θ = temperature

4 TERMINOLOGY

4.1 For the purpose of this standard, the following definitions in addition to those given in 4 of IS 8792 : 1995 shall apply.

4.2 Type Tests

Tests carried out to prove conformity with the specification. These are intended to prove the general qualities and design of a given type of line trap.

4.3 Routine Tests

Tests carried out on each line trap to check requirements which are likely to vary during production.

5 GENERAL CONDITIONS

5.1 The standard range of atmospheric conditions for carrying out measurements and tests is as follows:

Temperature	15°C to 35°C
Air pressure	86 to 106 kPa
Relative humidity	45 to 75 percent

Where it is impracticable to carry out measurements under the standard atmospheric conditions for testing, a note to this effect, stating the actual conditions, shall be added to the test report.

The temperature shall be substantially constant during a series of measurements carried out as a part of one test.

Where it is difficult to maintain the temperature within the limits specified above, the range may be extended beyond these limits either to 10°C or up to 40°C by mutual agreement.

5.2 For the tests, the line trap shall be mounted in a position similar to what it would be in service unless otherwise stated. The ambient temperature during the tests should be noted.

Some or all of the type tests may be repeated as sampling tests if specially agreed between manufacturer and purchaser. The tests on the protective device shall be carried out in a accordance with IS 3070 (Part 1) : 1985.

NOTE — For some of the tests specified in this standard particular methods are suggested in the interests of simplicity. Other methods including direct read-out instruments which eliminate or reduce computation, can be used providing their accuracy and suitability can be adequately demonstrated. It is important when carrying out carrier frequency measurements, to ensure that the measuring loop is kept as small as possible in order to exclude extraneous impedances. Also, all equipment used in such measurements (including the line trap) should be kept clear of metallic surfaces and objects and, where appropriate, the impedance of the test leads taken into account.

6 TESTS

6.1 Classification

The tests shall be classified as in **6.1.1** and **6.1.2**

6.1.1 *Type Tests*

The following shall constitute type tests:

a) Temperature rise test (**6.2**);
b) Measurement of radio influence voltage (**6.3**);
c) Impulse voltage test (**6.4.1**);
d) Power frequency voltage test on tuning device (**6.4.2**);
e) Short-time current test (**6.5**);
f) Measurement of the rated inductance of the main coil (**6.6**);
g) Measurement of power frequency inductance of the main coil (**6.7**);
h) Measurement of blocking resistance and blocking impedance (**6.8**);
j) Measurement of tapping loss and tapping loss based on the blocking resistance (**6.9**); and
k) Measurement of loss at power frequency (as agreed) (**6.10**).

6.1.1.1 Type tests shall be applied to one specimen which shall pass all tests for conformity to the standard.

6.1.2 *Routine Tests*

The following shall constitute routine tests:

a) Power frequency voltage test on tuning device (**6.4.2**);
b) Measurement of the rated inductance of the main coil (**6.6**);
c) Measurement of power frequency inductance of the main coil (**6.7**);
d) Measurement of blocking resistance and blocking impedance (**6.8**); and
e) Measurement of tapping loss and tapping loss based on the blocking resistance (**6.9**).

6.2 Temperature Rise Test

This test is designed to prove the thermal behaviour of the line trap at rated continuous current. The temperature rise of the main coil of the line trap (average value measured by increase in resistance and hot spot by direct methods) has to be determined.

The test should be carried out at rated continuous current (I_N) unless for any reason, this is impossible in which case a value (I_t) which is not less than 90 percent of the rated value is allowed.

The value of temperature rise θ_n which would have resulted from the rated continuous current is calculated from the formula:

$$\theta_n = \theta_t \left(\frac{I_N}{I_t}\right)^{1.6}$$

where θ_t is the temperature rise measured at I_t.

The test shall be continued until the temperature of any part of the line trap does not increase by more than 2 percent during two consecutive hourly readings.

6.2.1 *Determination of the Average Value of Temperature Rise Measured by Increase of Resistance*

Since the resistance of the main coil will vary with temperature depending on the temperature coefficient α of the conductor material, the temperature rise resulting from the application of rated continuous current can be ascertained by measuring the resistance immediately before the commencement of the test and calculating what it was immediately after the test. Since it is likely that a period of time will elapse between the completion of the test and the measurement of the resistance of the main coil, it is recommended that at least four measurements be taken at intervals of not more than 3 min and plotted against a time base. By extrapolating the resulting curve as shown in Fig. 1, the value of resistance at the moment of completion of the test will be obtained.

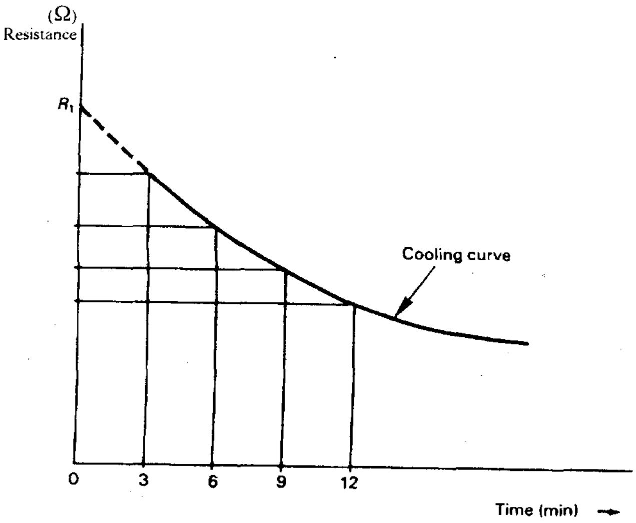


FIG. 1 METHOD FOR DETERMINING THE RESISTANCE OF THE MAIN COIL, AT COMPLETION OF TEMPERATURE RISE TEST

Values of temperature coefficient α and $T = 1/\alpha$ are given in Table 1 for copper, aluminium and aldrey. It is important that the manufacturer specifies the value of either α or T for the conductor material used.

Table 1 Values of α and T for Aluminium, Copper and Aldrey

(*Clause* 6.2.1)

Conductor Material	$\alpha = \frac{1}{T}$ (1/°C)	$T = \frac{1}{\alpha}$ (°C)
Aluminium	0.004 44	225
Copper	0.004 26	235
Aldrey	0.003 60	278

The temperature θ_2 of the main coil at the end of the test period shall be calculated from its measured resistance R_2 at that temperature and its measured resistance R_1 at some other temperature θ_1, using the following formulae:

— for aluminium : $\theta_2 = \frac{R_2}{R_1} \cdot (225 + \theta_1) - 225$

— for copper : $\theta_2 = \frac{R_2}{R_1} \cdot (235 + \theta_1) - 235$

— for aldrey : $\theta_2 = \frac{R_2}{R_1} \cdot (278 + \theta_1) - 278$

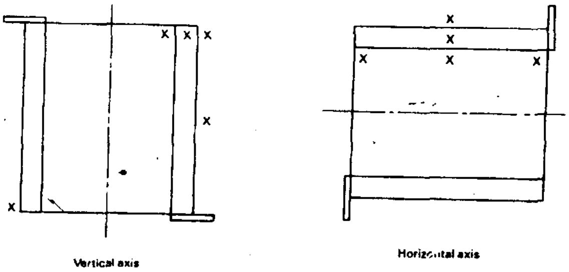
where θ_1 and θ_2 are measured in degrees Celsius [*see* IS 2026 (Part 2) : 1977].

The average temperature rise is the difference between the final temperature θ_2 and the ambient temperature.

6.2.2 *Determination of Temperature Rise at Hot Spot*

The hot spot temperature rise is the difference between the highest temperature reading obtained from a number of measuring points (at least 5) located as shown in Fig. 2 and the ambient temperature at the completion of the test.

It is possible to use thermocouples, thermometers, thermally sensitive paper or other suitable devices to measure the temperature rise. The measuring device shall be embedded in the coils on the surface of the conductor.



X = Location of measuring points

FIG. 2 LOCATION OF MEASURING POINTS IN MAIN COIL TO DETERMINE THE TEMPERATURE AT THE HOT SPOT

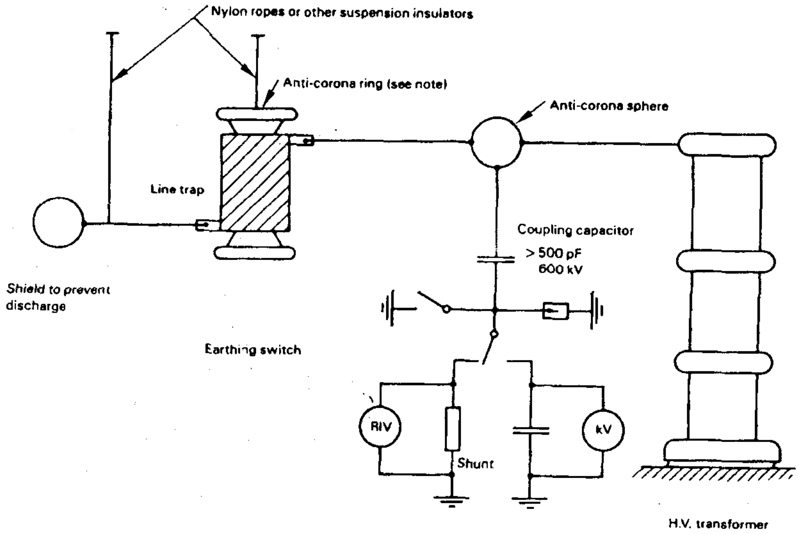
Temperature measurements using thermocouples may be difficult to carry out because the voltage across the main coil during the test can affect the readings. Where the axis of the main coil is vertical, the hot spot usually occurs at the top of the coil.

6.3 Measurement of Radio Influence Voltage

The recommended method of determining whether or not radio influence voltage would be generated by the line trap under service conditions is shown in Fig. 3. The environment in which the tests are carried out should be clean and dry. Also, the background interference level should not exceed 50 μV (*see* **12** of IS 8792 : 1995).

The tests should be carried out in accordance with IS 6209 : 1982 using equipment which is generally approved for the purpose and commercially available.

The equipment should be capable of measuring signals in a quasipeak mode in the band 0.5 MHz to 1.5 MHz within a 9 kHz bandwidth. The input impedance should be approximately 150 Ω.



NOTE — Anti-corona rings are to be used if they are required in service.

FIG. 3 METHOD OF INSTALLATION FOR DETERMINING THE RADIO INFLUENCE VOLTAGE *RIV* OF A LINE TRAP

6.4 Insulation Tests

It is only necessary to carry out one of the following tests subject to agreement between manufacturer and purchaser. In certain circumstances and subject to discussion and agreement between the two parties, it may be considered advantageous to carry out both tests.

6.4.1 *Impulse Voltage Test*

6.4.1.1 *Method 1*

The test is carried out with the protective device replaced by one having an impulse sparkover voltage at least 30 percent higher than the protective device which was delivered with the main coil and of the same type and construction. The method of connection should also be similar. The upper limit of the sparkover voltage should be that of the protective device having the next higher rating given in IS 3070 (Part 1) : 1985.

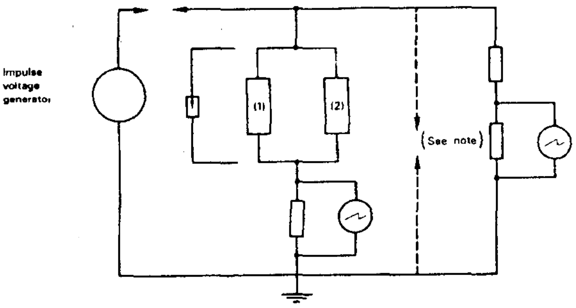
NOTE — It may be necessary to use a sphere gap in place of the protective device if the test requirements cannot be met due to the inherent characteristics of the protective device.

A voltage having a wave front of at least 200 kV/μs and an amplitude which ensures front of wave sparkover of the protective device, shall be applied to the line trap terminals. The recommended test circuit is shown in Fig. 4, but with the protective device connected instead of the chopping gap.

Test Procedure

The test voltage shall be applied to each terminal with the other earthed.

Oscillographic records should be obtained of all voltages and circuits as shown in Fig. 4.



NOTE — The chopping gap is included for the chopped impulse test only.

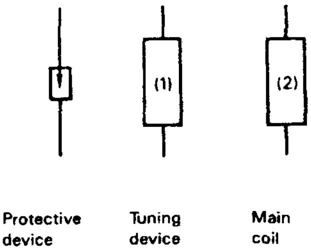


FIG. 4 MEASURING CIRCUIT FOR THE IMPULSE VOLTAGE TEST

Test Sequence:

a) One reduced impulse voltage at approximately 50 percent of the sparkover voltage of the protective device.

b) Five positive and five negative full impulse voltages as defined previously.

c) Repetition of item (a).

Significant variations in the blocking capabilities of the line trap prior to and after the impulse voltage tests, as well as variations in the oscillographic records, will indicate insulation abnormalities or other damage resulting from the tests.

6.4.1.2 *Method 2*

The test is carried out with the protective device disconnected and the tuning device connected in the manner that it would be in service.

A voltage having a wave shape of 1.2/10-50 μs shall be applied to the line trap terminals. The peak value of the voltage shall be at least 30 percent higher than the front of wave sparkover voltage or the residual voltage at nominal discharge current, whichever is higher. The recommended test circuit is shown in Fig. 4.

Test Pressure: See under 'Method 1'.

Test Sequence:

a) One reduced full impulse at approximately 50 percent of the required peak voltage as defined previously.

b) One 100 percent full impulse.

c) Two positive and two negative 100 percent chopped impulses with a maximum time to chopping of 5 μs and a maximum time of voltage collapse during chopping of 0.4 μs.

d) Three positive and three negative 100 percent full impulses.

e) Repetition of item (a).

Siginificant variations in the blocking capabilities of the line trap prior to and after the impulse voltage tests, as well as variations in the oscillographic records, will indicate insulation abnormalities or damage resulting from the tests.

NOTE — The chopping gap shown in Fig. 4 is included for the chopped impulse tests only.

6.4.2 *Power-Frequency Voltage Test on Tuning Device*

For the purpose of this test the tuning device is disconnected from the main coil and a test voltage $U_t = 1.3\ U$ applied to it for 5 s. The voltage U is evaluated in accordance with **11** of IS 8792 : 1995.

6.5 Short-Time Current Tests

6.5.1 These tests are designed to prove the mechanical and thermal withstand capabilities of the line trap at rated short-time current I_{KN} recommended values of which are given in **8.3** of IS 8792 : 1995. For the purposes of the tests, the line trap shall be complete, that is, the tuning and protective devices must be connected across the main coil.

6.5.2 *Mechanical Strength*

The mechanical strength of the line trap shall be proved by applying an asymmetrical short-time current, the first peak of which shall be not less than 2.55 times I_{KN}. The asymmetrical short-time current shall have a duration of at least 5 cycles. Other durations are a matter for agreement between manufacturer and purchaser.

6.5.3 *Thermal Behaviour*

The thermal behaviour of the line trap shall be proved by applying a short-time current I_{KN} for a duration of 1 s. If there are limitations in the test equipment, the thermal behaviour shall be proved by applying a current I for a time t such that $I^2 t$ is not less than $I^2_{KN} . t_N$, t having a value between 0.5 s and 2 s and t_N a value of 1 s.

The ability of the line trap to withstand this test shall be determined by visual inspection and measurement of the blocking capabilities before and after the tests. If the test cannot be carried out because of insufficient power capacity of the test equipment, the final temperature θ_1 shall be calculated as follows. It shall not exceed the maximum permissible temperature θ_2 as specified in Table 3.

$$\theta_1 = \theta_0 + aJ^2 t \ . \ 10^{-3}\ {}^\circ\text{C}$$

where

θ_0 = initial temperature (°C)

J = short-circuit current density (A/mm^2)

t = duration of the test (s)

a = function of $\frac{1}{2}(\theta_2 + \theta_0)$ in accordance with Table 2 $\left(\frac{{}^\circ\text{C} . \text{mm}^4}{A^2 . s}\right)$ where θ_2 is the maximum permissible average temperature in °C as specified in Table 3.

The initial temperature θ_0 shall be the sum of the ambient temperature and the relevant temperature rise measured by change in resistance.

NOTE — It is preferable to combine the mechanical strength and thermal behaviour tests for a duration of 1 s.

Table 2 Values of Factor a
(*Clause* 6.5.3)

$\frac{1}{2}(\theta_2 + \theta_0)$ (°C)	a = Function of $\frac{1}{2}(\theta_2 + \theta_0)$ $\left(\frac{°C \cdot mm^4}{A^2 \cdot s}\right)$	
	Copper	Aluminium
140	7.41	16.5
160	7.80	17.4
180	8.20	18.3
200	8.59	19.1
220	8.99	20.0
240	9.38	20.9
260	9.78	21.8

Table 3 Maximum Permissible Values of Average Temperature of the Line Trap (°C)
(*Clause* 6.5.3)

Insulation Class Temperature (°C)	Values of θ_2 Copper & Aluminium (°C)
105 (A)	180
120 (E)	200
130 (B)	250
155 (F)	250
180 (H)	250
220 (C)	300

6.6 Measurement of the Rated Inductance of the Main Coil

6.6.1 For the purpose of this measurement , it is recommended that the line trap be installed in such a way that there is at least one diameter separation from any metallic structures, objects or materials. The proximity of metal in any form can affect the accuracy of the measurement. All test leads should be kept as short as possible.

6.6.2 The recommended arrangement of test equipment is shown in Fig. 5.

L_{tN} = rated inductance of the main coil (H)
C_R = self-capacitance of the main coil (F)
R_x = equivalent resistance of the main coil (Ω)
C_B = variable capacitor
G = carrier frequency signal generator
R_B = variable resistor

C_B and R_B are adjusted for minimum reading on meter M at frequencies f_1 = 140 kHz and f_2 = 70 kHz. Values of $C_B = C_{B1}$ and C_{B2} respectively will be obtained.

$$L_{tN} = \frac{1}{4\pi^2 . (C_{B1} - C_{B2})} \frac{1}{f_1{}^2} - \frac{1}{f_2{}^2}$$

also $R_B = R_x$

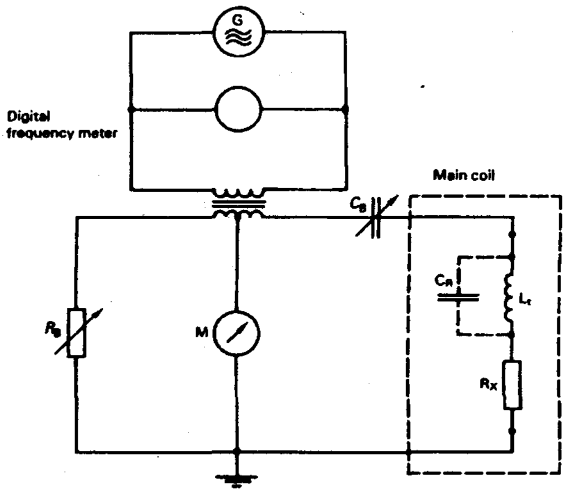


FIG. 5 MEASURING CIRCUIT FOR THE DETERMINATION OF THE TRUE INDUCTANCE OF THE MAIN COIL

6.7 Measurement of Power-Frequency Inductance of the Main Coil

This is carried out by voltage/current methods at power frequency or any frequency up to 100 Hz.

6.8 Measurement of Blocking Resistance and Blocking Impedance

The blocking resistance and blocking impedance of a line trap shall be determined within the specified bandwidth (impedance or resistive components as applicable) by means of the bridge method shown in Fig. 6. Equivalent methods of proven accuracy can also be used.

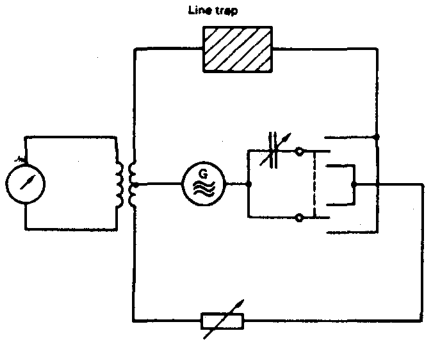


FIG. 6 MEASURING CIRCUIT FOR THE DETERMINATION OF THE BLOCKING IMPEDANCE

NOTE — In the case of line traps utilising simple resonance, it may be a matter for agreement between manufacturer and purchaser not to perform this test on all units of a series. It is then sufficient to determine the impedance at the tuning frequency and, for this purpose, the method of measurement shown in Fig. 7 is recommended. This method gives correct results only when the blocking impedance is resistive. At the tuning frequency, the voltage U_R is a minimum. Maintaining voltage U constant and varying R until $UR = U/2$ will give a value of R which will be equal to the blocking resistance of the line trap. The internal impedance of the generator should be small.

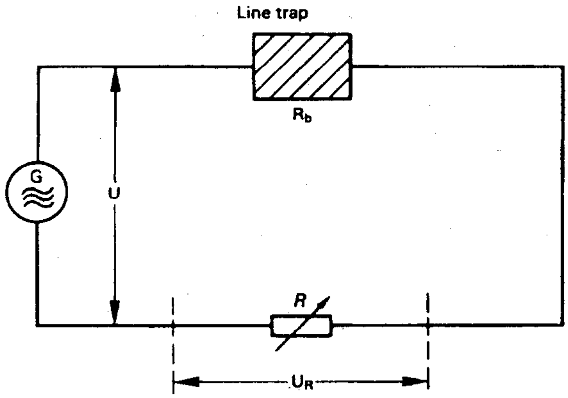


FIG. 7 MEASURING CIRCUIT FOR THE DETERMINATION OF THE BLOCKING RESISTANCE AT THE TUNING FREQUENCY IN THE CASE OF LINE TRAPS UTILISING SIMPLE RESONANCE

6.9 Measurement of Tapping Loss and Tapping Loss Based on the Blocking Resistance

6.9.1 A recommended method of determining the tapping loss is shown in Fig. 8. The tapping losses are calculated by the following equations:

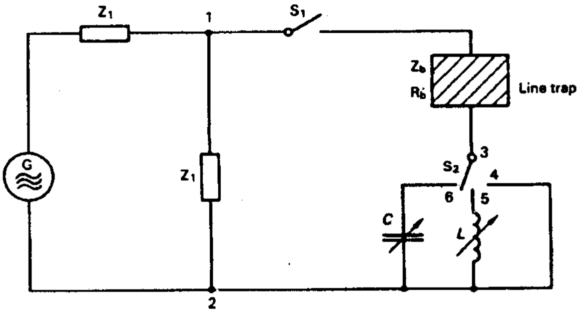


FIG. 8 MEASURING CIRCUIT FOR THE DETERMINATION OF TAPPING LOSS

Tapping loss (A_t) $= 20 \log_{10} \left| \frac{U_1}{U_2} \right|$ dB

$= 20 \log_{10} \left| 1 + \frac{Z_1}{2Z_b} \right|$ dB

Tapping loss based on the blocking resistance (A_{tR}) $= 20 \log_{10} \left| \frac{U_1}{U_2} \right|$ dB

$= 20 \log_{10} \left| 1 + \frac{Z_1}{2R_b} \right|$ dB

where

Z_1 = resistance equivalent to the characteristic impedance of the line

Z_b = blocking impedance

R_b = blocking resistance

U_1 = voltage at terminlas 1 and 2 when switch S_1 is open

U_2 = voltage at terminals 1 and 2 when switch S_1 is closed and switch S_2 is in position 3-4 (when measuring tapping loss) or position 3-5 (when measuring tapping loss based on the blocking resistance).

6.9.2 When measuring the tapping loss based on the blocking resistance, the reactive component of the impedance of the line trap shall be compensated for by adjusting capacitance C or inductance L, hence the alternative positions for switch S_2.

NOTE — If the measurement of the tapping loss is carried out in this manner, measurement of the blocking impedance and blocking resistance can be omitted and *vice versa*.

6.10 Measurement of Losses at Power Frequency

6.10.1 *General*

6.10.1.1 Since line traps vary widely in design and construction, it is recommended, for comparison purposes, that the losses should be corrected for a temperature of 75°C.

6.10.1.2 A method of correcting power losses with regard to temperature is given in **6.10.2** for guidance only.

6.10.2 *Measurement Method*

The measurement of total losses at rated frequency current requires special care because of the very low loss angle of a line trap. An appropriate method (for example, wattmeter, bridge, etc) shall be adopted by the manufacturer.

The total losses can be divided into those due to the d.c. resistance of the main coil and those due to eddy current losses in the windings and metallic parts of the line trap. Metallic structures in the near vicinity can also contribute to eddy current losses.

It is recommended that the losses should be measured, where possible, when the temperature of the windings is in the region of a reference temperature of 75°C. This can be done during the test described in **6.2**.

If this is not possible, the losses at the reference temperature can be determined by measuring the losses when the line trap is cold (temperature θ ° C) and carrying out the following culculations:

$$P_W = I_N^2 . R.K_1 + (P_c - I_N^2 R) . K_2$$

where

P_w = calculated total losses at 75°C

I_N = rated continuous power frequency current

R = d.c. resistance at θ°C

K_1 = factor for correcting d.c. resistance at θ °C to reference temperature

$= \dfrac{T + 75}{T + \theta}$ where $T = \dfrac{1}{\alpha}$ (*see* Table 1)

P_c = measured total losses at θ°C (cold state)

K_2 = factor for correcting eddy current losses to reference temperature (data obtained from a type tested line trap of similar construction)

$$= \frac{P_{wt} - I_N^{\,2} \,.\, R_t \,.\, K_1}{P_{ct} - I_N^{\,2} \,.\, R_t}$$

where

P_{wt} = measured total losses at 75°C

P_{ct} = measured losses at θ°C

R_t = d.c. resistance at θ°C

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